

site. The canyon above this dam site is relatively narrow, and a dam at this location would create a reservoir in many respects similar to that formed by Horse Mesa Dam on Salt River. The location is advantageous in that over 90 per cent of the drainage area of Verde River lies above this point and also it is the site closest to the centers of population in Salt River Valley.

Surveys have been made of this reservoir in the past, and the Bureau of Reclamation is now investigating the cost of a dam at this location. No definite information is at hand as to the cost of storage, but it probably would be in the neighborhood of \$100.00 per acre foot of gross capacity. In round numbers, a total expenditure of \$4,000,000 might be required for the construction of this dam and all appurtenant works.

By provision, therefore, of one comparatively small reservoir, waste out of the basin would occur only at times of extreme flood and substantially all of the water of Verde River would be made available for diversion to lands now under irrigation, much of which are today inadequately served. It is therefore clear that the maximum feasible development of the flow of this river for the benefit of existing projects can be accomplished by the expenditure of a much smaller sum than would be necessary for the storage of these flood waters over long periods of time for delivery to new lands outside of these projects.

Service to Existing Projects

Certain of the projects in the basin are now supplied directly by diversions from the surface flow of Verde and Salt Rivers. Others are supplied in part by return flow from irrigation of land in the Valley and partly by flood flows passing down the channel of Salt River. The available water supply, even when fully developed, will be no more than enough, if actually sufficient, for proper irrigation of all lands within existing projects. Consequently, it will be advisable to limit channel losses, in-so-far as it is economically feasible. There should then be included, in any rational plan of development for the benefit of all of the existing projects, means for delivery of the controlled flood water directly through canals, not only to farms in the Salt River Project, but to lands in contiguous projects, which are in need of and entitled to a proportion of any additional supply of water.

No definite estimate can now be made of the cost of providing for the transportation of this water through the canals of the Association and for connections to the present canal systems of the other projects. It is sufficient for present purposes that we anticipate the expenditure of \$500,000 for this work.

Summary of Verde Development

In brief, a rational plan of development of the water supply available in Verde River for the benefit of lands

dependent in part upon that supply and now inadequately supplied with water, would include a dam for flood regulation on that river, and canals and other facilities for the transportation of water so developed to such lands. Such a dam should provide for the storage of about 300,000 ac.ft. of flood water and the outlet works should be so arranged that the reservoir could immediately be drawn upon to the limit of the canal capacities of the various projects. By this means, an economy of construction would result and the maximum possible quantity of Verde water could be delivered to farms now in need of that water.

The Bartlett Dam and appurtenant works probably would cost in the neighborhood of \$4,000,000 and about \$500,000 additional would be needed for enlargement of canals of the Salt River Project and for other works to provide efficient delivery of this water to lands now under irrigation systems.

DEVELOPMENT ON SALT RIVER

No further storage development on Salt River need be contemplated under any rational plan, as the storage works now in service have sufficient capacity to prevent waste of Salt River water, except in years of extraordinary flood. This is clearly evidenced by the small amount of waste which has occurred on the average throughout the years that Roosevelt Dam has been in service. While waste did occur early after the construction of that dam and in

1915 and the two years following, and again in 1920, had the other reservoirs been in service and had the area dependent upon that supply been as great in those years as at present, the waste in all but 1916 would have been materially less. Since 1920, a period of 14 years, there has been no waste whatsoever.

Certain improvements, however, should be made to the works along Salt River, particularly to the spillways at the dams constructed by the Association during the past decade. Failure to complete these spillways and to provide proper protection for the power houses situated immediately below these dams will certainly result in serious damage and loss in event of another flood such as those of 1891, 1905, and 1916.

Conditions at Horse Mesa Dam are such that, if a large flood should pass Roosevelt Dam, the production of power probably would be interrupted for several months with the loss of several hundred thousand dollars of revenue, and major repairs to the spillway channels probably would have to be made. This is a condition which could well develop within two years should heavy rains occur this winter and next. We do not anticipate that the damage would be such as to jeopardize the safety of Horse Mesa Dam, but we are satisfied that a large flood would cause very severe damage and that major repairs would be immediately necessary. No definite estimate can be made of the cost of completion of the spillways at Horse Mesa

and of the cost of other work to provide adequate protection, but an expenditure of \$450,000 might well be required.

At Hermen Flat the situation is not serious, aside from the danger of many months interruption to power production at this plant, which would certainly follow the release of any flood over the spillway. In round numbers, as much as \$150,000 may have to be expended to prevent serious damage to this plant and loss of power revenue for many months.

At Stewart Mountain Dam the situation is somewhat more acute in that conditions may actually be dangerous, due to the fact that no effort was made to complete this spillway. There is less chance that the power plant at Stewart Mountain would be put out of service with attendant loss of revenue, but no flood of magnitude can be passed through the spillway gates without endangering the safety of Stewart Mountain Dam in some degree. A proper spillway escape channel must be constructed before there is any likelihood of a major flood entering that reservoir. No detailed estimate is available, but the cost probably will not be less than \$250,000 nor more than \$350,000 for the completion of the Stewart Mountain development.

In order to provide as much effective storage as possible in all of the reservoirs on Salt River, gates were installed in all of the spillways. The normal full reservoir level has thereby been raised in each case by

the height of the gates and the natural freeboard on the dam reduced in the same amount. While the provision of these gates was undoubtedly justified economically, it must be recognized that they are somewhat of a hazard. In the first place, there will be less flattening of floods than would be the case with simple overflow spillways and consequently greater discharges through the spillways. Second, the operation of these gates is entirely dependent upon human effectiveness under difficult conditions.

We do not suggest that the gates be removed, but we do advise the installation of positive automatic devices which will open the gates at the proper time, regardless of any shut-down of motors or engines and without reliance upon any human for operation. The above estimates include an allowance for automatic operation of the spillway gates at Horse Mesa, Mormon Flat and Stewart Mountain. Additional funds should be provided for similar improvements at Roosevelt.

When Roosevelt Dam was built, a diversion dam was constructed across Salt River above the head of the reservoir and a canal was built to the site of the dam. Water carried through this canal was used in the generation of power for construction and for the operation of the cement plant. In subsequent years the diversion dam was permitted to fall into disrepair and eventually it was washed out. Although the rehabilitation of this canal

around Roosevelt Reservoir would not add to the safety of any of the storage works or help insure the continuity of power production, it would result in greater revenue to the Association. Due to the higher and constant head at which the power unit served by this canal can be operated, it is advantageous to carry water through it whenever the level of Roosevelt Reservoir falls much below the spillway. At low stages of the reservoir especially, the output of power at Roosevelt could be increased materially by the operation of this unit. The cost of reconstruction of the intake dam and of rehabilitation of the power canal has been estimated at about \$150,000 by the Association. Such an expenditure would be advisable.

Summary of Salt River Development

In order to insure the safety of existing structures and in order to prevent serious interruption of power production for long periods at the plants along Salt River, as much as \$1,000,000 may be required. In addition, the expenditure of about \$150,000 on the rehabilitation of the power canal around Roosevelt Reservoir would be desirable from the standpoint of revenue.

GENERAL SUMMARY

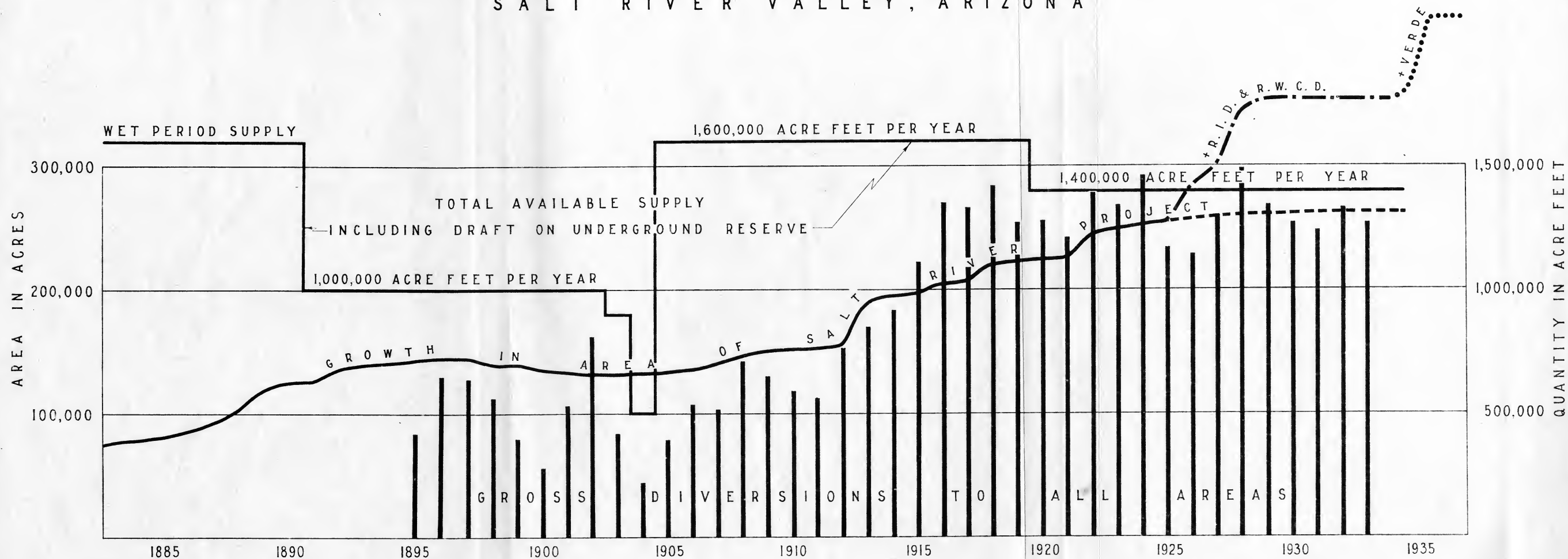
During such a period of drouth as that preceding the floods of 1905, not more than 1,000,000 acre feet per year could have been obtained from the flow of Salt River and Verde River even with full development of all surface and

underground storage. During the wet years following 1905 approximately 1,600,000 acre feet would have been available, but since 1920 the supply would have been limited to 1,400,000 acre feet per year, even with full development. The Salt River Project and other irrigation projects dependent upon diversions by Salt River Valley Water Users' Association comprise an area in excess of 350,000 acres. In addition, there are other areas which are dependent in some degree upon the flow of Verde River. It is therefore apparent that the entire water supply could be used on lands within existing projects and that no water can be diverted to new lands without a corresponding deduction from the supply needed by areas now under irrigation. Actually, the future of the Salt River Valley would be more assured if there were some reduction in the area now under irrigation.

Rational development of the water supply of Verde River for the benefit of lands now under irrigation, and conservation of present developments on Salt River would involve the expenditure of from \$5,500,000 to \$6,000,000. Construction of these works could be carried on at a rapid rate; in fact, every effort should be made to complete the spillways at the dams on Salt River before the flood season a little more than a year from now.

Approximately \$4,000,000 of the total would be for the construction of a dam on Verde River for the benefit of lands now under irrigation which are dependent in part

GROWTH OF IRRIGATION, AND MAXIMUM AVAILABLE WATER SUPPLY OF THE SALT RIVER VALLEY, ARIZONA



on the waters of that river and which are in need of an additional supply. The expenditure of the balance would make it possible to deliver this water to these lands efficiently and would provide protection to the existing works of the Association, on which the prosperity of the entire Salt River Valley depends.


RAYMOND A. HILL

August 30, 1934.

NATIONAL PLAN FOR CONSERVATION
OF
WATER RESOURCES OF SALT RIVER VALLEY

Records of the flow of Salt River and Verde River have been kept over the past forty-five years, and for some time previous to the commencement of actual stream measurements there are sufficient data to enable one to determine approximately the relative supply of water.

Prior to 1891, there was a period of more than average runoff culminating in the great flood of 1891. For a number of years thereafter, the supply was less than normal, and in 1898 there started the most severe drouth within historical times. This was not broken until 1905, when a series of floods occurred. From 1905 to 1920 the runoff was again materially in excess of normal, and it was during these years that the Salt River Project was developed. But after the flood of 1920, the flow of the rivers was again generally less than average. This second period of deficiency has not yet been ended, and there is, of course, the possibility that it may continue and be as severe as the great drouth of thirty years ago.

Maximum Available Supply

If before the flood of 1891 there had been built on Salt River and on Verde River all of the storage works

feasible of construction, and if the underground reservoir in the Salt River Valley had also been tapped by as many wells as now exist, the supply of water during the next fourteen years would have been entirely insufficient to serve adequately the lands which are now dependent upon the flow of these rivers. Actually, the total diversion from the surface streams and all pumping from underground could not together have averaged as much as 1,000,000 acre feet per year over this period of drouth.

Beginning with the flood of 1905 and continuing to the flood of 1920, as much as 1,600,000 ac.ft. of water could have been diverted from surface streams and pumped from underground for service to lands in the Salt River Valley. In the early years of this wet period there would have been unavoidable waste of water due to the occurrence of successive major floods, exceeding the combined capacities of all reservoirs practicable of construction.

From 1920 to the present time, however, the total supply of water available to lands in the Salt River Valley could not have exceeded 1,400,000 ac.ft. on the average, even with regulation in all possible reservoirs and with heavy draft upon the underground reserve.

The validity of these estimates is clearly evidenced by the following facts: first, the combined discharge of the Salt and Verde Rivers averaged less than 1,000,000 ac.ft. per year from 1891 to 1904, inclusive; second, the combined natural flow of these rivers during the 30 years

since 1904 has been practically 1,650,000 ac.ft. per year on the average, and during the last 25 years the average has been less than 1,450,000 ac.ft. per year.

Consequently, it must be recognized that a safe supply of more than 1,400,000 ac.ft. per year cannot be obtained from the Salt River and Verde River combined. While it is true that some additional water would be available in wet periods, it is clear from the historical records that even this service would have to be curtailed about 30 per cent over a long period of years, in event of the recurrence of such a drouth as the one preceding the floods of 1905. Even if one were to disregard that drouth as something never to occur again, and were to assume that shortages over the past few years would have been justified, it is still evident that little more than 1,400,000 ac.ft. per year from these sources could justifiably be considered.

Substantially no other source of supply is available to lands in the Salt River Project and other projects east of the Agua Fria River, since the contribution from local desert watersheds is nominal in comparison with the flow of the Salt and Verde Rivers. Areas to the west, below the confluence of the Gila and Agua Fria Rivers, receive a material part of their supply from these sources, with the exception of the Roosevelt Irrigation District, which is largely dependent on diversions by the Salt River Valley Water Users' Association.

Necessary Flow Out of Valley

Were the waters of Salt River and Verde River perfectly pure, all of the water available for diversion could be consumed within the basin without injury to the lands in the Salt River Valley. Actually, however, large quantities of various salts are dissolved in the waters of these rivers, averaging about 600 parts per million. This proportion of salt is equivalent to over 0.8 ton per acre foot; consequently, 1,400,000 acre feet of this water contains a total of more than 1,100,000 tons of salts.

It is obvious that as much salt must be taken out of the Valley as is brought in by the waters of these rivers; otherwise there would be an accumulation which eventually would render the farm lands unfit for cultivation. Under the conditions which prevail, the water which naturally drains out or is pumped out of the Salt River Valley for drainage has approximately four times the concentration of salts as the river waters. A volume of drainage water equal to one-quarter of the inflow to the basin will thus carry away as much salt as is brought in by the waters of Verde and Salt Rivers.

It is apparent, therefore, that the consumption of water on lands within the Salt River Valley must not exceed three-quarters of the gross diversions and that an average of substantially 350,000 acre feet of water must drain out naturally or be pumped from underground and be carried out of the Salt River Valley each year.

The salts brought into the lower valley by Gila River, Agua Fria River, and other streams augment the amount brought in by the water which drains or is pumped out of the Salt River Valley. Consequently it is necessary to the continuance of agriculture in this area that the outflow at Gillespie dam carry with it as much salt as is brought into the entire basin by Gila River and all its tributaries.

Draft on Supply

For many years the area of land under irrigation in the Salt River Valley was much smaller than it is today, and the gross diversions of water to supply these lands were generally less than the amounts available. In recent years, however, the reverse has been true, due to continued expansion, until today there is more land under canals in this valley than can adequately be served.

Prior to the construction of Roosevelt Dam there was no regulation of the flow of Salt River, and service to lands then in cultivation was limited to the natural flow of Verde River and Salt River. Consequently, it was only in flood years that the gross diversions were sufficient to satisfy all needs, and then only when the diversion works were not washed out by the floods.

After the construction of Roosevelt Dam, however, the floods of Salt River were held back in that reservoir and sufficient water became available to the lands in the Valley then in cultivation. It is important to recognize

that, during these years, the gross diversions were in general at least 5 ac.ft. per acre, and that there was a marked parallelism between the increase in the acreage within the Salt River Project and the magnitude of all diversions. This condition prevailed until early in the last decade when expansion and overdevelopment became the custom rather than the exception.

During the past ten years the irrigable area dependent upon diversions from the flow of Verde River and Salt River by the Salt River Valley Water Users' Association was enlarged more than one-third until a total of 355,000 acres became dependent on such diversions. This total includes 40,000 acres of land west of the Agua Fria River within the Roosevelt Irrigation District, which is supplied largely from wells within the Salt River Project. As a result of this expansion of acreage without the possibility of adding any water to that available in the Salt and Verde Rivers, the ratio of gross diversions to the acreage under irrigation systems gradually decreased. For a few years attempts were made to serve all of the lands within these new projects, but gradually the cropped area was reduced until today there are tens of thousands of acres of idle land under canals in the Salt River Valley.

It should be apparent to any dispassionate observer that immediate steps should be taken to improve the present situation by conserving the floods of Verde River for the benefit of land in the Salt River Valley now

inadequately supplied. It should be equally apparent to those without prejudice that the diversion of any of this water to new land would merely aggravate the condition of shortage which today exists. The only question should be, how can improvement of conditions best be accomplished.

CONSERVATION OF FLOOD WATERS OF VERDE RIVER

From the earliest days of settlement in the Salt River Valley until the construction of Roosevelt Dam, it was the custom to divert all water available in Verde River and Salt River to the limit of the capacity of the diversion works. After the construction of Roosevelt Dam, the floods in Salt River were held back, permitting the use of this water at times when the natural flow of the streams was insufficient to supply all of the area under cultivation. Thereafter, it has been the custom to divert all of the low flow of Verde River and generally all of the flood flow up to the limit of the capacity of the diversion works at Granite Reef and at other points along Salt River below the mouth of Verde River.

In the wet years following the construction of Roosevelt Reservoir, the area under irrigation in the Salt River Valley was much smaller than at present. Consequently, a much larger amount of the flood waters of Verde River were not diverted than would have been the case under present conditions with the larger acreage now dependent upon that supply. During the current sub-normal period, however, and particularly in more recent years, most of

the flow of Verde River has been used on existing farm lands and it has been only in the case of a few large floods that any of this water has been wasted.

It is on account of this situation that any development for the benefit of new lands would be dependent entirely upon that part of infrequent floods which would be wasted out of the basin. This excess water would have to be stored in reservoirs large enough to permit a supply to be drawn out for many years without replenishment. Such a procedure is obviously uneconomical and would have doubtful justification, even if there were no areas within Salt River Valley now inadequately served.

Rational development of the water supply available in Verde River requires neither large storage nor long carry-over through dry years. The waters of Verde River can best be made available to lands now inadequately served by the regulation of the floods to an amount which can be diverted into the existing canal systems and delivered to the lands which need this water.

When the development of Verde River is considered from the standpoint of alleviating present conditions, it is readily determined from the records of flow that approximately 300,000 ac.ft. of usable storage would make the control of that river so complete that no water would ever be wasted, except during years of extreme flood. For example, during the ten dry years from 1895 to 1904, inclusive, the runoff of Verde River averaged 334,000 ac.ft.

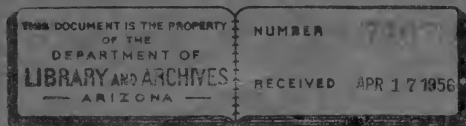
and every bit of water could have been regulated down to a maximum of 3,000 c.f.s. with no more than 300,000 ac.ft. of effective storage. During the sixteen wet years from 1905 to 1920, inclusive, 95% of the total runoff could have been reduced to a quantity divertible at Granite Reef alone. Actually, the runoff in these years averaged 717,000 ac.ft. and the unavoidable waste would have averaged only 35,000 ac.ft. per year, most of which would have occurred in the single year of 1905. During the fourteen years from 1921 to 1934, the runoff of Verde River averaged 459,000 ac.ft. per year, and practically all of this could have been regulated in a 300,000 ac.ft. reservoir and used beneficially on lands within existing projects now dependent in part upon the flow of that river.

Any materially greater amount of storage would not be proportionally effective; in fact, if 400,000 ac.ft. of storage were provided, there would be no increase in yield during dry years and but little increase even in years of much more than normal runoff. On the other hand, a reservoir materially smaller than 300,000 ac.ft. would not be large enough to regulate all of the flood flow in a number of years. Consequently, it appears that about 300,000 ac.ft. of usable storage capacity should be provided as far down on Verde River as is practicable.

For many years it has been known that there is a favorable dam site on Verde River about five miles above Camp Creek, which has come to be known as the Bartlett

RATIONAL PLAN FOR CONSERVATION
OF
WATER RESOURCES OF SALT RIVER VALLEY

AUGUST 30, 1934



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LOS ANGELES, CALIFORNIA

August 30, 1934.

The President and Board of Governors,
Salt River Valley Water Users' Ass'n.
Water Users' Building,
Phoenix, Arizona.

Gentlemen:

There is submitted herewith our report "Rational Plan for Conservation of Water Resources of Salt River Valley". This report summarizes the information and recommendations presented to you and to the Council of the Association at the joint meeting held on August 27th, at which the following resolution was separately adopted by the Board of Governors and the Council of the Association:

"BE IT RESOLVED, by the Council and Board of Governors of the Salt River Valley Water Users' Association, that the officers of this association are authorized and directed to immediately make application to such governmental agencies as may be empowered to loan money for the hereinafter described purposes, for a loan or loans in such amount or amounts as may be necessary; first, to build storage works on the Verde river; second, to repair and complete our dams and spillways on the Salt river; third, to rehabilitate the power canal; fourth, and to build such other works on the Salt river project as are necessary to complete the same, and that the officers of this association be authorized and directed to negotiate repayment contract or contracts with such governmental agencies and to do and perform such other and necessary acts as are necessary in the premises, provided, however, that any additional water developed by such works be for lands now under irrigation having existing rights."

Respectfully submitted,


RAYMOND A. HILL

RAH/AH